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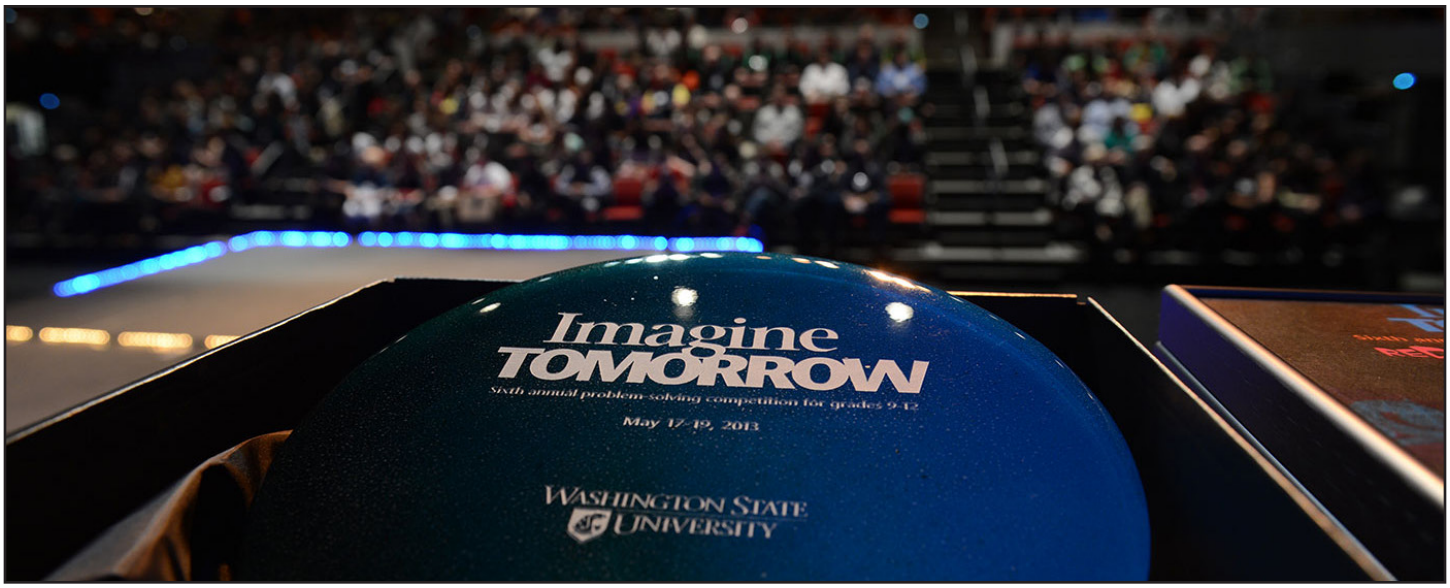

2013 Imagine Tomorrow Awards Ceremony. Photo by Bob Hubner

Imagine Tomorrow

Raising Bioenergy Literacy for High School Students and Teachers

The NARA Imagine Tomorrow program is designed to engage high school students to develop creative solutions for society's energy challenges in the area of biofuels. The program's intent is to raise bioenergy literacy among high school students and teachers with the long-term objective of preparing a future workforce and populace to participate in a biofuel industry.

To accomplish this task, NARA is engaged in three primary tracks:

1) Support the Imagine Tomorrow competition

2) Provide training and resources to teachers and students

3) Conduct program assessments

The Imagine Tomorrow Competition

NARA is a major sponsor of the Imagine Tomorrow competition held annually at Washington State University. NARA's participation allowed this event to expand from hosting only Washington state student teams to hosting teams from Washington, Oregon, Idaho and Montana. In addition, the competition now includes a "biofuels challenge" added to the previous categories of behavior, design and technology.

On May 18th, 2013, the sixth annual Imagine Tomorrow competition was held at Washington State University. Participation increased this year with 133 student teams total (112 in 2012) and 18 teams (14 in 2012) in the "biofuels challenge" category. Topics covered in the biofuels challenge covered biogas, biodiesel and ethanol production from a variety of feedstocks. Over 130 judges from throughout the Pacific Northwest and representing varied industries and disciplines reviewed and ranked the projects. The top four ranked teams in each category, plus the highest ranked first time participating school, were awarded cash prizes for the students and the schools . In addition, special award categories such as 'Most likely to Succeed in the Marketplace' or 'Global Impact' were established to reward team success.

For more information about Imagine Tomorrow and to review judge and student comments, visit imagine.wsu.edu

Resources and Training for Teams

In an effort to increase the quality of team projects and the number of student participants, NARA's Education Team took a proactive approach directed at Idaho schools. The University of Idaho's MOSS (McCall Outdoor Science School) delivered a summer workshop and an annual Biofuel Teacher Institute for 9-12 grade teachers. Over 60 teachers participated in the workshops. Teachers who requested assistance to prepare their students for the Imagine Tomorrow competition were paired with MOSS graduate students. Eleven Idaho Imagine Tomorrow teams were mentored by MOSS graduate students and entered the competition. MOSS plans to expand the mentoring to other states next year.

"I wouldn't be brave enough to get a team together without MOSS", said Sharon Cates, a chemistry teacher from Capitol High School in Boise Idaho who organized two teams to compete; "My principal has become fully committed to this event and we are already preparing for next year." MOSS graduate students met and stayed with high school teams for up to one week during the project's development and then remained in touch via email, phone and

through a blog. According to James Casey, a MOSS mentor and University of Idaho graduate student in the department of Natural Resources, the initial meetings were helpful to shape the project. “These guys really pushed us with questions” said Lee Brown, who brought three teams to compete from Rocky Mountain High School in Meridian, ID.

Not only did the teachers and students benefit from the interaction, but the graduate students from MOSS were rewarded as well. Carrie Anderson is working through a master’s degree in education at the University of Idaho. Most of her experience has been with elementary school programs. Having an opportunity to work with high school students and teachers broadened her education and reconfirmed her passion to connect students with the environment.

Conducting Program Assessments

An assessment is in place to evaluate the effects of Imagine Tomorrow on students’ STEM career choices and energy literacy. In 2012, this NARA Education Team conducted a preliminary STEM student survey with a 35% response rate. The survey asked students to rate their interest in STEM careers after participating in the Imagine Tomorrow competition. 42% of the students who responded indicated they were more interested in STEM careers after participating in Imagine Tomorrow while 39% stated that their interest level remained the same. These surveys were expanded in 2013 to include information on career choices and interest in the various fields related to energy. Future tracking is anticipated to longitudinally track education and career paths of past participants. To measure the level of energy literacy gained, Imagine Tomorrow competition abstracts from 2009 through 2012 were scored. Scoring revealed that the energy and bioenergy literacy content in the abstracts improved over the years. Information on the competition products such as posters, PowerPoint presentations and models was also collected for assessing energy literacy improvements from the competition post the abstract phase.

2013 Imagine Tomorrow 1st place winners in Biofuels Category from Henry M Jackson High School, Mill Creek, WA. Team members: Indira Rayala, Hannah Cho, and Celia Evans. Presentation Title: *The Effects on Methane Production During the Anaerobic Digestion of Cow Manure Along with Biodegradable Plastic*.

The effect of teacher workshops conducted through MOSS was also assessed by survey information with the following results:

- All participants showed a statistically significant increase in content knowledge related to biofuels, water resources and climate change.
- In a 9-month follow-up survey, 68% of teachers report being more likely to use a problem-based learning pedagogy after being involved in a MOSS teacher workshop.
- 90% of teachers report that they learned new ways of teaching.
- 66% percent of teachers agree or strongly agree that they have a good understanding of biofuels, that they understand key parts of the supply chain and that they have enough of an understanding to have developed an informed opinion about the feasibility of a woody biomass biofuel program in the Pacific Northwest.
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Mapping Supply Chain Assets in Western Oregon and Washington

Opening a dialogue with stakeholders

NARA held its first open meeting for interested stakeholders in the western Oregon and Washington region. The purpose of this meeting was to introduce the NARA project and leadership to all interested stakeholders and begin a partnership to establish a supply chain coalition in western Oregon and Washington.

The event was held on May 21st, 2013 at the Washington State University campus in Vancouver, Washington. Invitations were extended to potential stakeholders identified by the NARA Outreach Team from previous enquiries and meetings, and a news release was distributed to the local press. Twenty-two stakeholders representing governmental agencies, non-profits and business enterprises attended the meeting.

An equal number of NARA representatives were present to share NARA's progress in defining supply chain assets in the Western Montana Corridor and to receive stakeholder comments on how to improve the supply chain analysis process in the western Oregon and Washington region. A number of presentations were made from NARA Outreach, Education and Systems Metrics Team members followed by comments and questions from the stakeholders.

Moving forward

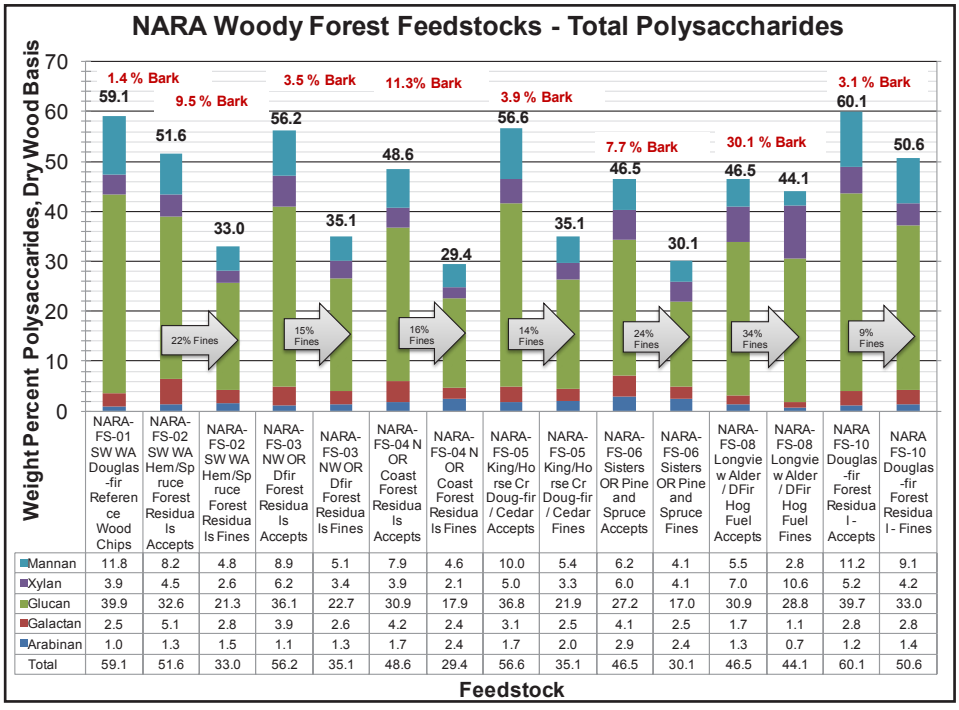
As a follow-up to the May meeting, the NARA Outreach and Education Teams have initiated steps to enable stakeholder collaboration to the supply chain analysis. Much of the supply chain analysis will be coordinated through the IDX course. In order for the IDX team to document and analyze the regional assets, accurate information needs to be provided from regional stakeholders. NARA has established a web-based mechanism to enable two-way data transfer between stakeholder collaborators and NARA members.

NARA will develop a project roadmap for the region that defines the target area for analysis, a description of how the work will be completed and lists the analyses to be performed. Once completed, the project roadmap will be widely distributed to NARA members and regional stakeholders.

Ultimately, involving stakeholders in the research process and using their input to shape the supply chain analysis is an important step. The interest and enthusiasm demonstrated at the Vancouver meeting is an encouraging sign that regional participation is forthcoming. To become involved as a stakeholder and receive information relating to upcoming events and progress made, please register.

Characterizing various feedstocks

Gevan Marrs at Weyerhaeuser generated the figure below. Packed with useful information, it is often used in NARA presentations. The purpose of this article is to define elements in the figure and provide some analysis. A bulk of the information presented in the figure relates to the amount of polysaccharides contained in various woody feedstocks. Polysaccharides are long molecules made up of simple sugars (monosaccharides) bound together. Within the NARA project, the simple sugars derived from wood polysaccharides are used to make isobutanol, which is then converted into biojet fuel. Simply put, biojet fuel in the NARA process is derived from wood polysaccharides. There are different types of polysaccharides found in wood and those are listed as mannan, xylan, glucan, galactan and arabinan.



	NARA-FS-01 SW WA Douglas-fir Reference Wood Chips	NARA-FS-02 SW WA Hem/Spruce Forest Residuals Accepts	NARA-FS-02 SW WA Hem/Spruce Forest Residuals Fines	NARA-FS-03 NW OR Dfir Forest Residuals Accepts	NARA-FS-03 NW OR Dfir Forest Residuals Fines	NARA-FS-04 N OR Coast Forest Residuals Accepts	NARA-FS-04 N OR Coast Forest Residuals Fines	NARA-FS-05 King/Horse Cr Doug-fir / Cedar Accepts	NARA-FS-05 King/Horse Cr Doug-fir / Cedar Fines	NARA-FS-06 Sisters OR Pine and Spruce Accepts	NARA-FS-06 Sisters OR Pine and Spruce Fines	NARA-FS-08 Longview Alder / DFir Hog Fuel Accepts	NARA-FS-08 Longview Alder / DFir Hog Fuel Fines	NARA FS-10 Douglas-fir Forest Residual - Accepts	NARA FS-10 Douglas-fir Forest Residual - Fines
Mannan	11.8	8.2	4.8	8.9	5.1	7.9	4.6	10.0	5.4	6.2	4.1	5.5	2.8	11.2	9.1
Xylan	3.9	4.5	2.6	6.2	3.4	3.9	2.1	5.0	3.3	6.0	4.1	7.0	10.6	5.2	4.2
Glucan	39.9	32.6	21.3	36.1	22.7	30.9	17.9	36.8	21.9	27.2	17.0	30.9	28.8	39.7	33.0
Galactan	2.5	5.1	2.8	3.9	2.6	4.2	2.4	3.1	2.5	4.1	2.5	1.7	1.1	2.8	2.8
Arabinan	1.0	1.3	1.5	1.1	1.3	1.7	2.4	1.7	2.0	2.9	2.4	1.3	0.7	1.2	1.4
Total	59.1	51.6	33.0	56.2	35.1	48.6	29.4	56.6	35.1	46.5	30.1	46.5	44.1	60.1	50.6

The term "feedstock" in this case refers to the plausible residual softwood to be used in the wood residue to biojet fuel conversion process. Each feedstock sample has a designated code (FS-01, FS-02…) and is distinguished by either species/location or degree of cleanliness. All of the feedstock samples were chipped, screened and air-dried. Note that each feedstock (except FS-01) is divided into

two segments: fines and accepts. Fines are small wood particles that go through a 1/8 inch gyratory screen, accepts are wood chips that do not pass through the screen.

Polysaccharides, fines and bark content

The figure illustrates that polysaccharide content in wood residuals varies significantly depending on species with Douglas-fir residuals containing up to 60% total polysaccharides in the accepts fraction. Polysaccharide type, represented by varied colors within the vertical bars, also varies. The percentage of chipped wood material that is reduced to fines when screened ranges from 34% of sample FS-08 (hog fuel is mill wood waste typically used as boiler fuel) to 9% in sample FS-10. The percentage of bark present in the "accepts" fraction is shown in red numbers and ranges from 30.1 % in sample FS-08 to 1.4% in sample FS-01.

Feedstock logistics, economic and downstream considerations

Note that those samples containing the least amount of bark content show the greatest value of total polysaccharides. Gevan Marrs draws the following conclusion relating bark content to feedstock costs: "the lowest bark content occurs in pulp-type chips, which carry a significantly higher price due to market competition for those chips. Dropping the cost tier significantly into the forest residuals category, but only compromising the eventual sugars yield by minimizing the bark content and fines losses seems to be the most promising feedstock supply strategy. Accordingly, a relatively low-bark (3-5%) Douglas-fir forest residuals type is desired as the near-term target feedstock." He goes on to make the following recommendations based on the information presented in the figure:

1) Forest residuals sampled to date, with existing chipping / grinding processes have a relatively high fines content, and those fines are also high in bark and ash. Some removal of these fines by screening is likely to be beneficial, but at a cost of losing part of the feedstock. Studying the optimization of this tradeoff is likely to be an important factor for overall feedstocks economic contribution to the process.

2) Bark in the Pacific Northwest softwoods diminishes the total polysaccharides available for fermentation to isobutanol by having about 1/3 the starting amount compared to wood. This suggests investigating more closely how collection and harvesting practices could be modified, at minimal added cost, to achieve a reduced bark content to give a higher conversion yield. (None of the operations that have been sampled to date are sensitive to bark content, so productivity per hour driving down costs has been the goal.)

3) The minus 1/8-inch fines screened out to date have very high ash contents—so high as to almost certainly be intolerable. Since screening out fines impacts feedstock cost, it suggests investigating how much harvesting practices can alter this without significantly reducing productivity and driving unit costs up. Again, until operators are aware of a need to pay attention to this aspect, productivity is likely to be the main goal.
These conclusions should help guide efforts to minimize overall conversion costs and provide valuable outreach information to stakeholders.

The FS-01, FS-03 and FS-10 samples have been pretreated, enzymatically hydrolyzed and the hydrolysate has been supplied to Gevo for isobutanol conversion using their yeast biological catalyst. As further samples are evaluated in the conversion process, the data contained in this figure provide a valuable baseline used to compare downstream conversion results for each sample to original feedstock characteristics.

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